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RELATIVE FATIGUE RESISTANCE OF THREE LIGHT STANDARD BASE CONNECTION DESIGNS

By

Eric F. Nordlin, Paul G. Jonas and C. B. Kendrick

INTRODUCTION

In-service fatigue failures of lighting standard bases have caused some concern about the fatigue strength of the base joint design presently in use (Fig.1-Joint C-1) and raised the possibility that two alternate designs (Fig.1-Joints C-2 and C-3) might offer superior fatigue strength.

The relative nominal bending fatigue strengths of welded joints simulating sections through joints from each of these three types of lighting standard base connection designs were compared by conducting harmonic fatigue tests on four specimens from each joint.

CONCLUSIONS

These tests indicate that the nominal fatigue strengths of joints C-1, C-2, and C-3 at 100,000 cycles are 31, 37, and 54 Ksi, respectively. However, since fatigue data was limited by having only one low-cycle specimen from joint C-1 and only one high-cycle specimen from joint C-3 with only four tests of each type of joint being performed and since this test method did not duplicate the fatigue loading imposed on a lighting standard base joint in service, the differences in the fatigue test performances of the three types of joints were not considered sufficient to justify any positive conclusions about their relative fatigue strengths. Moreover, when the results of test performances for all the joints are considered as a group (see Figure 7), the correlation suggests that the fatigue strength of these joints in these tests is governed mostly by factors common to all three joints rather than by an differences in the design of these joints. Hence, it is recommended that further fatigue testing in bending on simulated joint sections be discontinued in favor of vibration fatigue tests on full scale lighting standards. Since the full scale tests are considerably more costly, they should be conducted only if and when operational experiences justify them in the future.

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GENERAL OBSERVATIONS

A full scale lighting standard can be subjected to cyclic reversed deflection by using a shaker to energize it harmonically. This type of fatigue loading duplicates the service failure conditions. However, testing in this fashion is tedious and expensive. Hence, low cost small scale harmonic fatigue tests of sections of simulated lighting standard base joints were substituted for the full scale tests. These tests fatigued the simulated base joints in reversed bending rather than in tension-compression as observed in service failures.

In each test, specimens (prepared as shown in Figure 2) simulated a section through one wall of the pole shaft welded to a segment of the base with the joint to be tested. This joint section was harmonically flexed about its own axis using a shaker table as shown in Figure 3. The results of these tests are shown in Tables 1, 2 and 3, and in Figures 4, 5, and 6.

The data curve of nominal stress (based on deflection) versus cycles for each specimen was plotted on a log log graph. The rapid roll off each curve at the point where the specimen failed, clearly defined the point of failure in each test.

The fatigue limit curve is conventionally assumed to be a straight line on a log log graph of cycles versus stress. The best straight line tangent at the failure point to all the data curves for a set of specimens was taken to define the fatigue limit line for that set of specimens. The tangent points for each set of data curves were estimated and used to derive this line by the least squares method. These points and derivations are shown in Tables 4 through 7. The relative locations of the estimated tangent points and these lines were such that iterative calculations were considered unnecessary.

The nominal fatigue stress limits appear to be quite high. Examinations of the steel used to make the specimens indicated that it had an ultimate strength of about 80 Ksi. Lateral constraint in these type of joints could permit the material to be stressed to the level and cycles shown by the fatigue limit lines. However, the uncertainty in the magnitude of these stresses was such that the tests were evaluated on a relative rather than an absolute basis.

FATIGUE TEST DATA

TABLE 1

Joint C-1

SPECIMEN 1		SPECIMEN 2		SPECIMEN 3		SPECIMEN 4	
±Ksi Stress	Cycles	±Ksi Stress	Cycles	±Ksi Stress	Cycles	±Ksi Stress	Cycles
39.2	0	30.5	0	38.4	0	63.2	0
39.2	29,400	28.3	63,000	38.4	18,000	61.05	840
36.6	73,950	27.9	176,400	29.3	58,500	52.3	1,680
34.9	81,750	27.9	222,600	25.8	85,500	52.3	6,720
32.1	85,650	26.2	298,200	23.7	127,500	48.1	10,920
16.0	95,790	21.8	333,300	23.7	144,300	38.4	15,120
		21.8	334,080	23.7	198,900	34.2	15,900
		20.9	345,780	11.8	295,500	25.8	16,680
		17.5	369,180			24.4	17,460
		8.8	392,580			20.9	18,180
						10.5	18,840

FATIGUE TEST DATA

TABLE 2

Joint C-2

SPECIMEN 1		SPECIMEN 2		SPECIMEN 3		SPECIMEN 4	
±Ksi Stress	Cycles	±Ksi Stress	Cycles	±Ksi Stress	Cycles	±Ksi Stress	Cycles
42.0	0	55.8	0	83.9	0	58.6	0
42.0	33,600	52.3	480	79.2	320	49.9	4,500
39.6	60,600	52.3	960	69.3	620	47.5	45,000
32.4	87,600	52.3	1,860	59.3	920	45.1	69,000
32.4	133,800	51.6	3,660	58.6	6,320	39.6	90,000
31.6	138,000	50.2	5,460	54.5	13,040	39.6	106,800
31.3	142,200	48.1	10,860	52.3	21,440	30.1	123,600
15.7	146,100	48.1	29,340	49.1	25,640	28.5	157,200
		34.9	37,980	49.1	29,840	28.5	168,900
		34.9	38,760	49.1	42,440	14.3	172,500
		33.5	40,200	39.6	45,560		
		16.8	40,860	39.6	50,240		
				19.8	53,840		

FATIGUE TEST DATA

TABLE 3

Joint C-3

SPECIMEN 1		SPECIMEN 2		SPECIMEN 3		SPECIMEN 4	
±Ksi Stress	Cycles	±Ksi Stress	Cycles	±Ksi Stress	Cycles	±Ksi Stress	Cycles
65.1	0	102.9	0	100.2	0	105.7	0
64.1	5,100	85.4	1,080	91.9	510	91.9	510
61.7	30,600	76.8	2,160	89.1	1,020	86.4	1,020
59.9	45,900	76.8	5,220	85.0	2,040	79.5	4,080
42.8	50,700	68.6	7,380	82.3	4,080	75.4	6,120
21.4	53,400	59.0	8,400	79.5	6,120	68.6	8,160
		54.9	7,360	54.9	7,080	52.1	9,120
		34.3	10,320	27.4	7,980	26.0	10,020
		17.2	11,220				

TABLE 4

Points on C-1 Data Curves Tangent to C-1 Fatigue Limit Line

X (log cycles)	Y (log stress)
5.44091	4.43616
5.3784	4.36173
4.84819	4.57054
4.00432	4.68034

LINEAR REGRESSION TO A LEAST SQUARES FIT

N = 4
MEAN OF X = 4.91795
MEAN OF Y = 4.51219
STANDARD DEVIATIONS: OF X = 0.664601; OF Y = 0.141536
EQUATION: Y = -0.201295 X + 5.50215 (Fatigue Limit Line of Joint C-1)
COEFFICIENT OF CORRELATION = -0.945208
STANDARD ERROR OF THE ESTIMATE = 0.0565921

TABLE 5

Points on C-2 Data Curves Tangent to C-2 Fatigue Limit Line

X (log cycles)	Y (log stress)
4.81291	4.66464
5.1271	4.51322
4.64048	4.69197
4.5092	4.67578

LINEAR REGRESSION TO A LEAST SQUARES FIT

N = 4
MEAN OF X = 4.77243
MEAN OF Y = 4.6364
STANDARD DEVIATIONS: OF X = 0.267165; OF Y = 0.0828852
EQUATION: Y = -0.281338 X + 5.97906 (Fatigue Limit Line of Joint C-2)
COEFFICIENT OF CORRELATION = -0.906842
STANDARD ERROR OF THE ESTIMATE = 0.0427846

TABLE 6

Points on C-3 Data Curves Tangent to C-3 Fatigue Limit Line

X (log cycles)	Y (log stress)
4.66276	4.77815
3.78533	4.90309
3.76716	4.87622
3.72591	4.88762

LINEAR REGRESSION TO A LEAST SQUARES FIT

N = 4
MEAN OF X = 3.98529
MEAN OF Y = 4.86127
STANDARD DEVIATIONS: OF X = 0.45233; OF Y = 0.0564963
EQUATION: Y = -0.121809 X + 5.34671 (Fatigue Limit Line of Joint C-3)
COEFFICIENT OF CORRELATION = -0.975247
STANDARD ERROR OF THE ESTIMATE = 0.0152988

TABLE 7

Points on C-4 Data Curves Tangent to C-4 Fatigue Limit Line

X (log cycles)	Y (log stress)
5.44091	4.43616
5.3784	4.36173
4.84819	4.57054
4.00432	4.69636
4.81291	4.66464
5.1271	4.51322
4.64048	4.69197
4.5092	4.67578
4.66276	4.77815
3.78533	4.90309
3.76716	4.87622
3.72591	4.88762

LINEAR REGRESSION TO A LEAST SQUARES FIT

N = 12
MEAN OF X = 4.55856
MEAN OF Y = 4.67129
STANDARD DEVIATIONS: OF X = 0.615496; OF Y = 0.176149
EQUATION: Y = -0.265124 X + 5.87987 (Fatigue Limit Line of combined Joints)
COEFFICIENT OF CORRELATION = -0.926389
STANDARD ERROR OF THE ESTIMATE = 0.06957

Figure 1

TESTED POLE BASE CONNECTIONS

NOTE

These diagrams are schematic only and are drawn for the purpose of showing the types and locations of the welds involved in the three connection designs.

Ref. California Division of Highways 1969 Standard Plans; Pages 198, 204, 208 and 209

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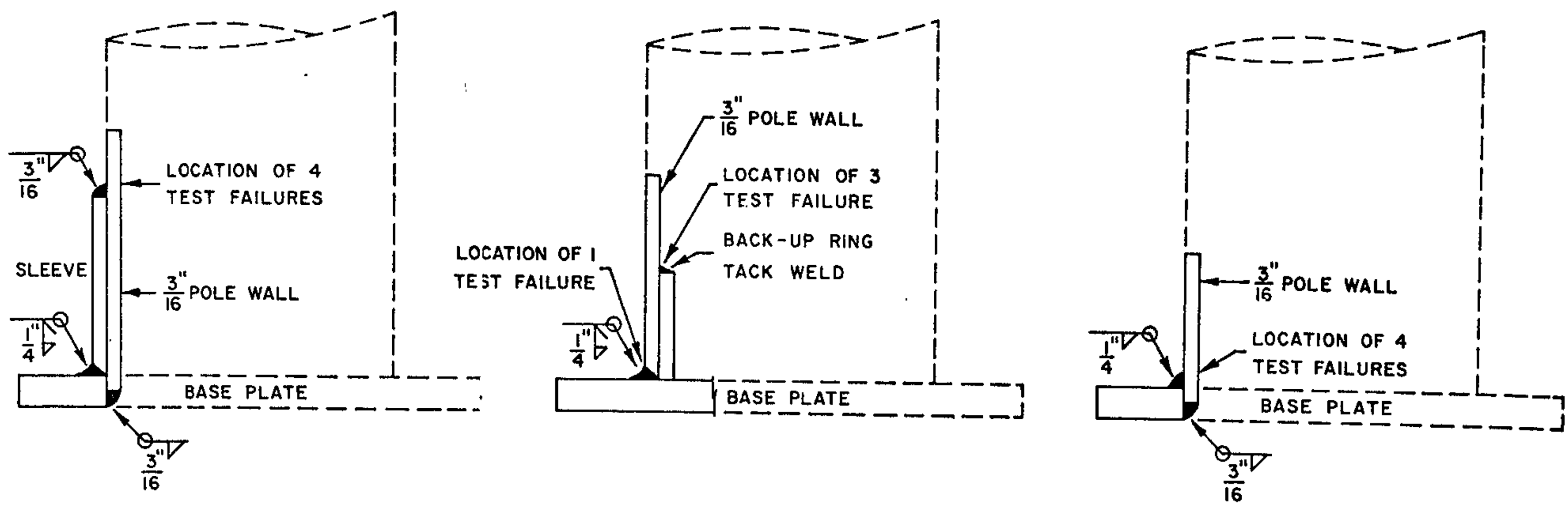


JOINT C-3 JOINT C-2 JOINT C-1

Figure 2

TEST SPECIMENS

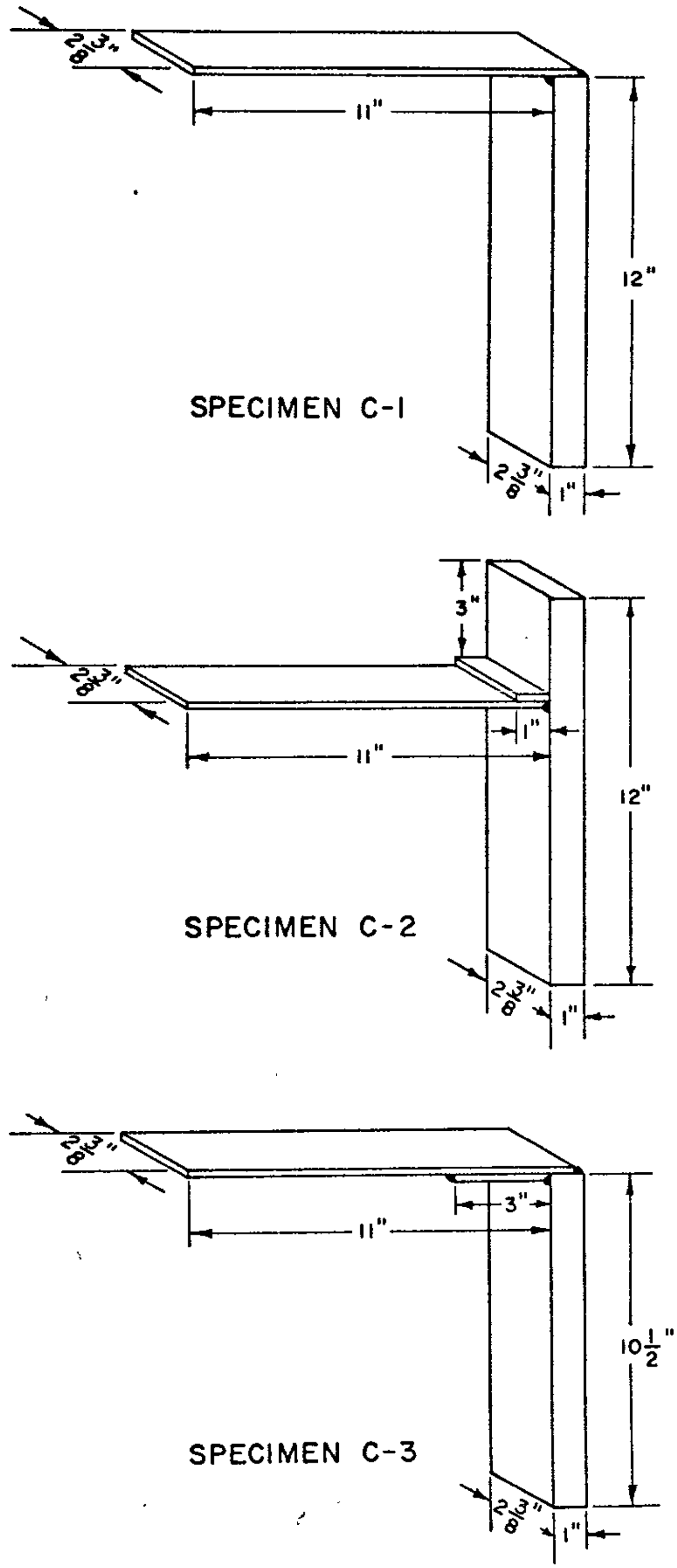
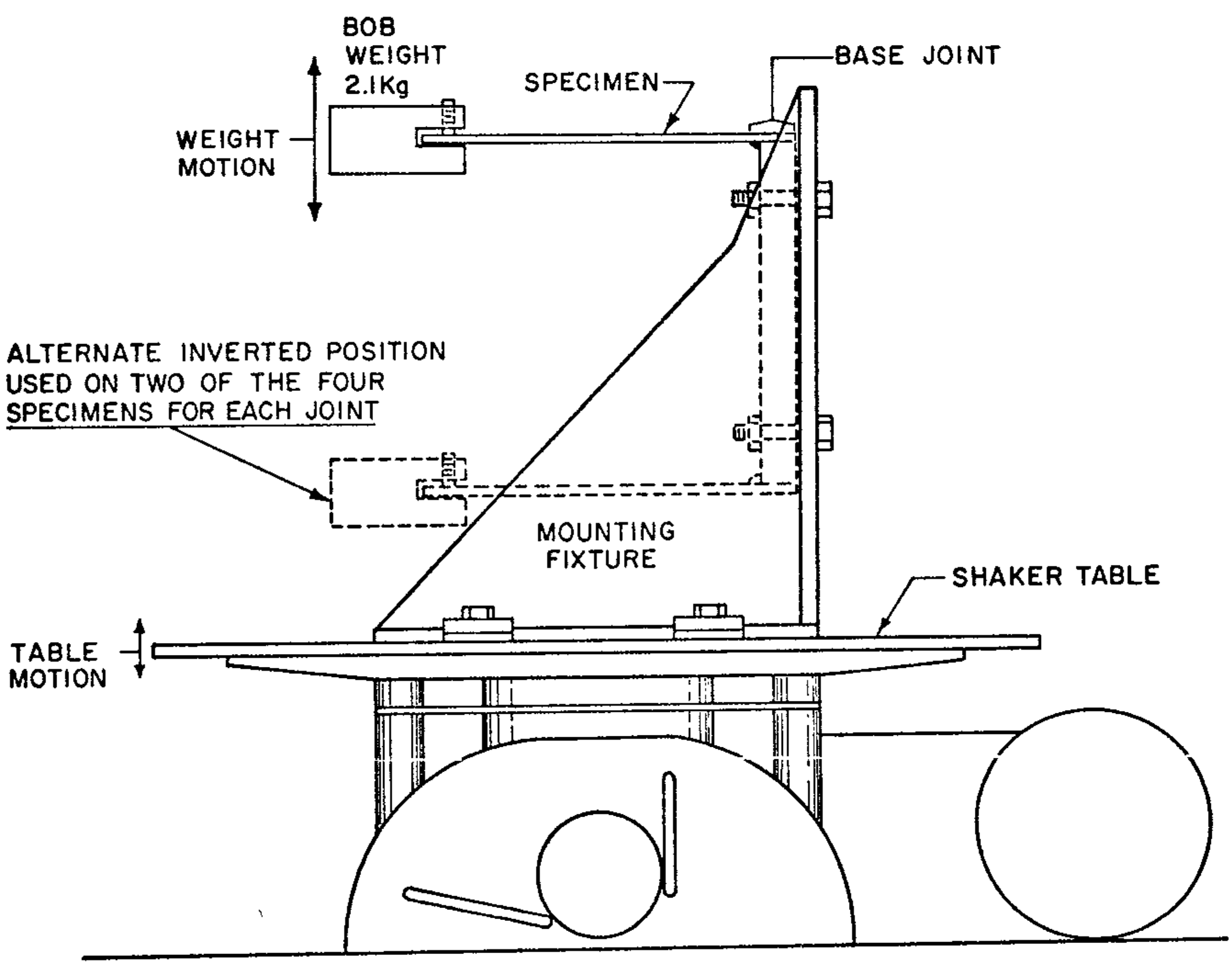


Figure 3

TESTING FIXTURE



FATIGUE STRENGTH OF SIMULATED LIGHT STANDARD BASE JOINT TYPE C-I TESTED IN REVERSED BENDING ABOUT JOINT AXIS

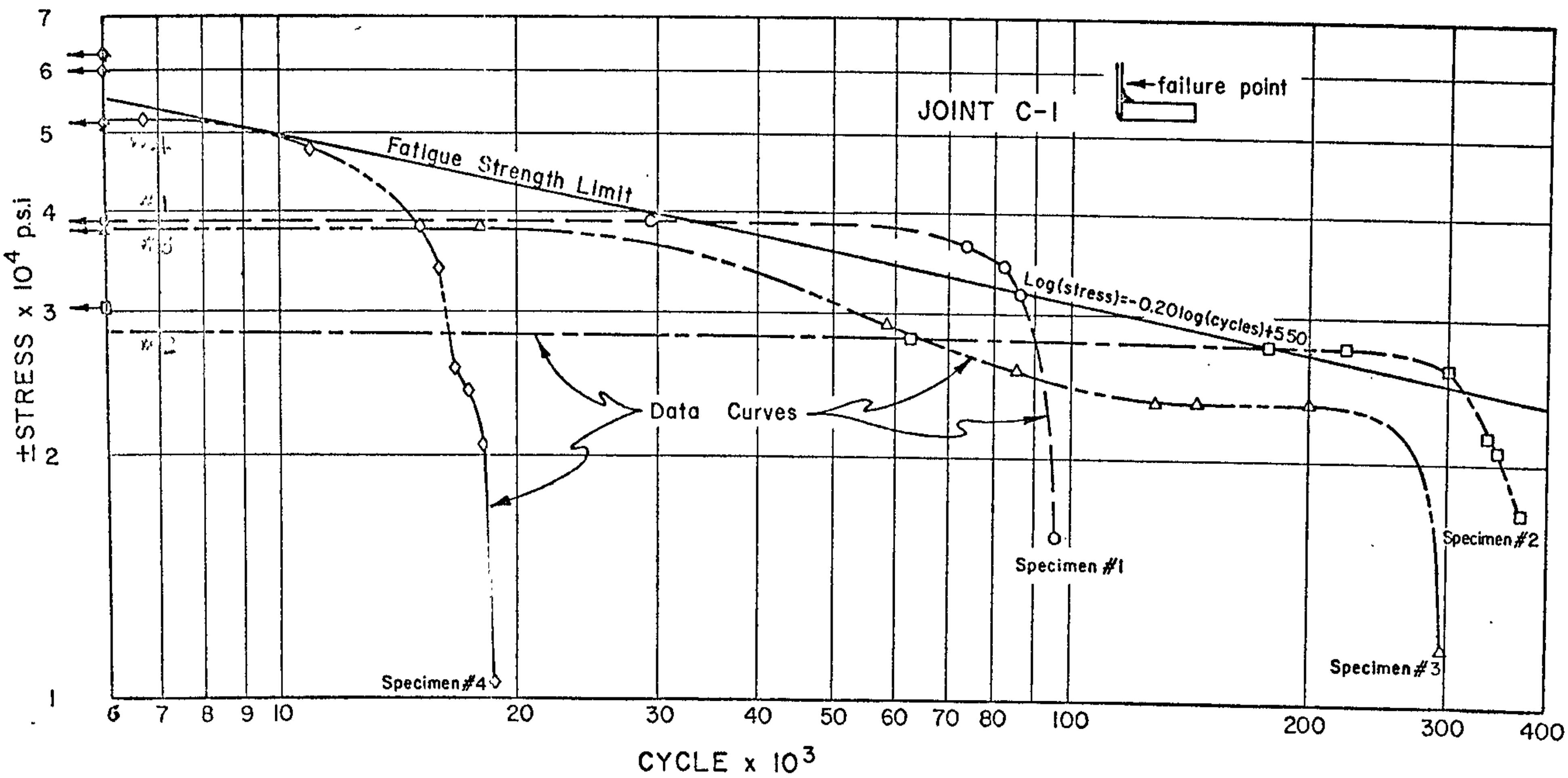


Figure 5

FATIGUE STRENGTH OF SIMULATED LIGHT STANDARD BASE JOINT
TYPE C-2 TESTED IN REVERSED BENDING ABOUT JOINT AXIS

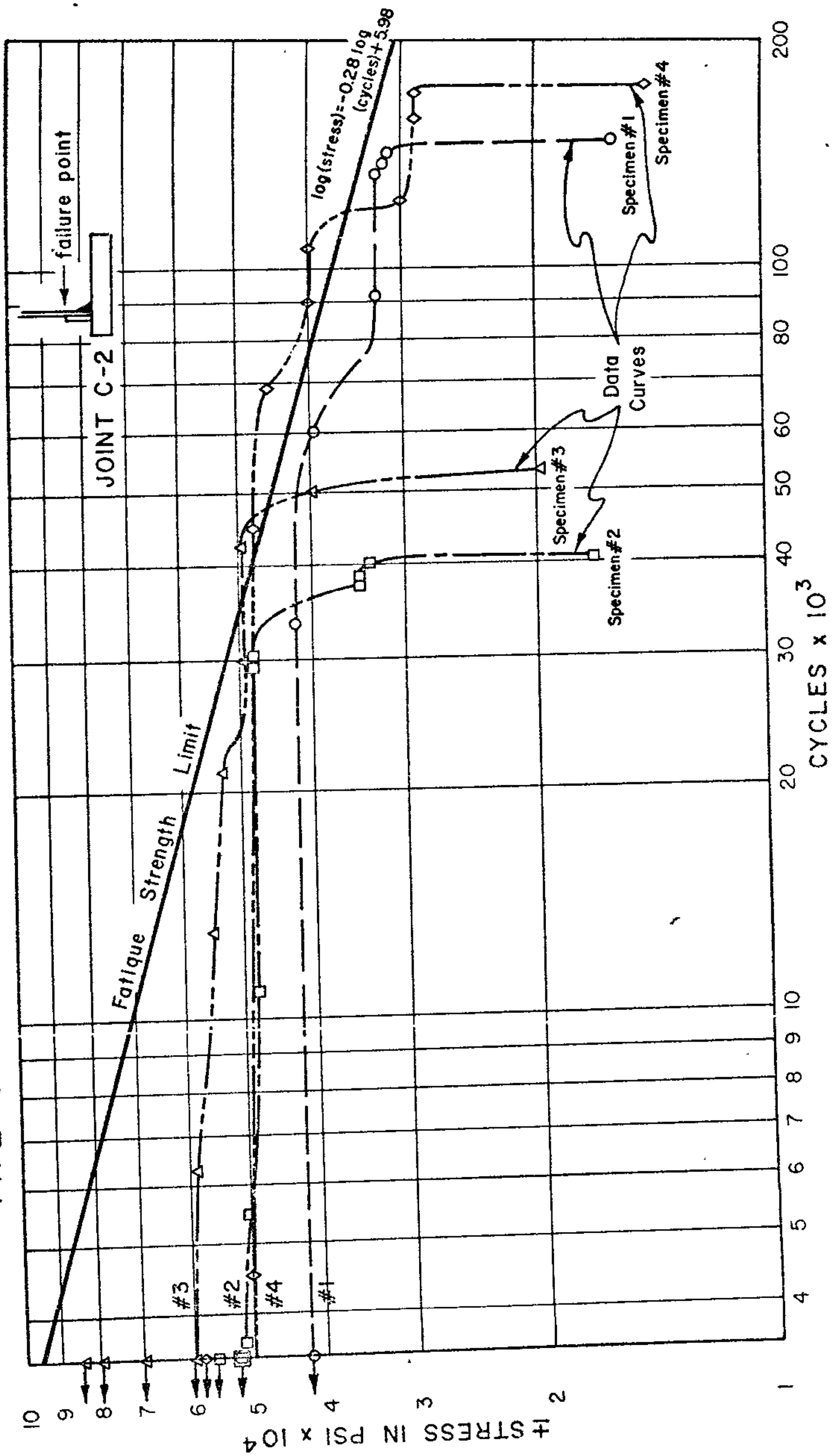


Figure 6

FATIGUE STRENGTH OF SIMULATED LIGHT STANDARD BASE JOINT
TYPE C-3 TESTED IN REVERSED BENDING ABOUT JOINT AXIS

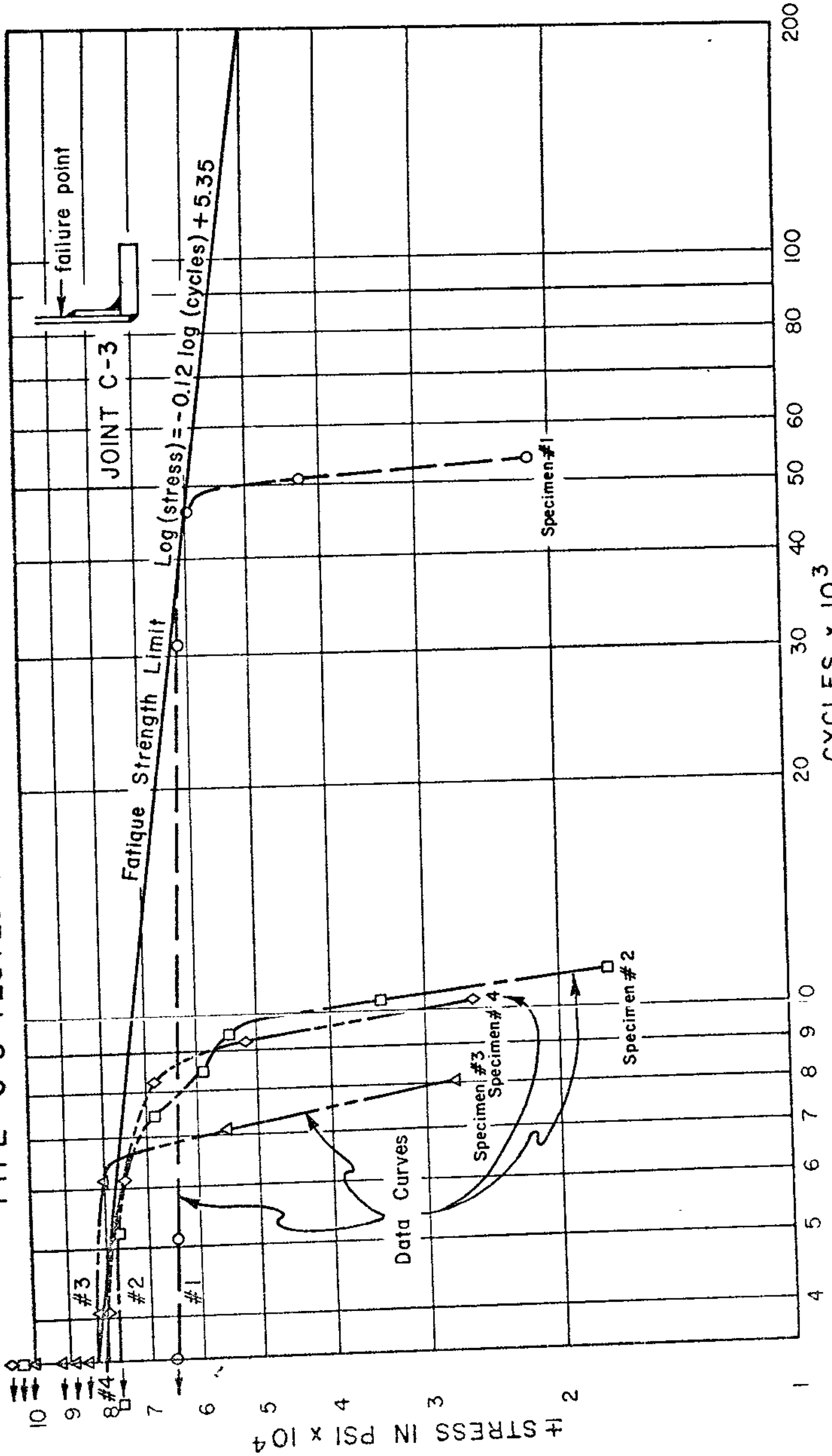


Figure 7

RELATIVE FATIGUE STRENGTH LIMITS FOR 3 TYPES OF SIMULATED LIGHT STANDARD BASE JOINTS IN REVERSED BENDING ABOUT THE JOINT AXIS SHOWING THE CORRELATION COEFFICIENT FOR EACH SET OF DATA